Claims

1. A method of reinforcing a fiber composite laminate in a Z direction comprising the steps of:

providing a composite preform having composite fibers extending generally in an X-Y plane;

placing a mat of discrete fibers on the composite preform;

providing at least one needle having at least one external barb;

pushing the needle through the mat of discrete fibers and the preform generally in the Z direction, such that the barbs catch some of the discrete fibers and pull the discrete fibers through the preform;

retracting the needle so as to leave the discrete fibers in the preform;

repeatedly adjusting the position of the needle relative to the preform and pushing the needle through the mat of discrete fibers and the preform, thereby defining a pass through the preform and creating a selected pattern of Z-direction reinforcement fibers in the preform.

2. The method according to claim 1, wherein the discrete fibers are fiberglass.

3. The method according to claim 2, wherein the fiberglass discrete fibers are S-glass discrete fibers.

4. The method according to claim 1, wherein the discrete fibers are graphite.

5. The method according to claim 1, wherein the discrete fibers are polymers.

6. The method according to claim 1, further comprising the steps of:

adjusting the position of the preform; and

repeatedly adjusting the position of the needle relative to the preform and pushing the needle through the mat of discrete fibers and the preform, thereby defining a second pass through the preform and increasing the density of the Z-direction reinforcement fibers in the preform.

7. The method according to claim 6, further comprising the step of:
replenishing the mat of discrete fibers with additional discrete fibers prior to the second pass through the preform.

8. The method according to claim 6, further comprising the step of:
making additional passes through the preform.

9. The method according to claim 8, further comprising the step of:
replenishing the mat of discrete fibers with additional discrete fibers prior to each pass through the preform.

10. The method according to claim 1, wherein the step of providing a needle with one or more external barbs is achieved by providing a needle having at least one portion with a polygonal or elliptical cross-sectional area, the barbs being coplanar flush barbs disposed at one or more of the corners of the polygonal or elliptical cross-sectional area.

11. The method according to claim 1, further comprising the step of:
curing the composite preform with a resin material.

12. The method according to claim 1, wherein the discrete fibers are inserted through the preform so as to create Z-direction fibers that protrude outward from the preform.

13. The method according to claim 12, further comprising the step of:
exposing the Z-direction fibers that protrude outward from the preform so as to provide a means of transferring heat from the preform.

14. The method according to claim 12, further comprising the steps of:
curing the composite preform with a resin material; and

preventing the Z-direction fibers that protrude outward from the preform from being infused with the resin material.

15. The method according to claim 12, further comprising the steps of:
curing the composite preform with a resin material; and
allowing the resin to infuse into the Z-direction fibers that protrude outward from the preform.

16. The method according to claim 1, further comprising the step of:
providing a layer of resilient material in association with the preform;
pushing the needle through the layer of resilient material as well, such that the resilient material catches and retains the discrete fibers as the needle is retracted;
removing the resilient material after the last pass through the preform.

17. The method according to claim 16, wherein the resilient material is silicon rubber.

18. The method according to claim 1, further comprising the step of:
providing a layer of soluble material in association with the preform;
forcing the needle through the layer of soluble material as well, such that the discrete fibers protrude outward from the preform into the soluble material;
wicking the soluble material into the discrete fibers, thereby preventing resin from wicking into the discrete fibers during a curing process; and
exposing the protruding discrete fibers by removing the soluble material after the curing process.

19. The method according to claim 1, further comprising the step of:
providing a layer of meltable material in association with the preform;
forcing the needle through the layer of meltable material as well, such that the discrete fibers protrude outward from the preform into the meltable material;
wicking the meltable material into the discrete fibers, thereby preventing resin from wicking into the discrete fibers during a curing process; and

exposing the protruding discrete fibers by removing the meltable material after the curing process.

20. The method according to claim 19, wherein the meltable material is thermoplastic.

21. The method according to claim 1, wherein the preform is tackified to hold the composite fibers in place.

22. A method of bonding at least two composite preforms together comprising the steps of:

providing at least two composite preforms, each composite preform having composite fibers extending generally in an X-Y plane;

inserting discrete fibers through each preform generally in a Z direction, so as to form exposed Z-direction fibers and loops protruding outward from each preform;

overlapping the exposed Z-direction fibers and loops from one preform with the exposed Z-direction fibers and loops from another preform;

infusing a resin material through each preform and the overlapped Z-direction fibers and loops;

co-curing the preforms, thereby bonding the preforms together.

23. The method according to claim 22, wherein the discrete fibers are fiberglass.

24. The method according to claim 23, wherein the fiberglass discrete fibers are S-glass discrete fibers.

25. The method according to claim 22, wherein the discrete fibers are graphite.

26. The method according to claim 22, wherein the discrete fibers are polymers.

27. A method of bonding two composite preforms together comprising the steps of:

providing at least two composite preforms, each composite preform having composite fibers extending generally in an X-Y plane;

associating a layer of soluble material with each of the preforms;

inserting discrete fibers through each preform and each layer of soluble material generally in a Z direction, so as to form Z-direction fibers and loops protruding outward from each preform into the soluble material;

infusing a resin material into each preform;

preventing the resin material from wicking into the Z-direction fibers and loops with the soluble material;

curing each preform;

removing the soluble material from each cured preform to expose the Z-direction fibers and loops;

overlapping the exposed Z-direction fibers and loops from one preform with the exposed Z-direction fibers and loops from another preform; and

bonding the preforms together by disposing an adhesive material in the overlapped exposed Z-direction fibers and loops.

28. The method according to claim 27, wherein the discrete fibers are fiberglass.

29. The method according to claim 28, wherein the fiberglass discrete fibers are S-glass discrete fibers.

30. The method according to claim 27, wherein the discrete fibers are graphite.

31. The method according to claim 27, wherein the discrete fibers are polymers.

32. The method according to claim 27, wherein prepregs are substituted for preforms.

33. The method according to claim 27, wherein a meltable material is substituted for the soluble material.

34. The method according to claim 33, wherein the meltable material is thermoplastic.

35. An apparatus for reinforcing in a Z direction a composite preform having composite fibers in an X-Y direction comprising:

a base plate having a lower array of needle apertures;

a middle plate disposed above the base plate, the middle plate having an aperture for retaining a volume of discrete fibers, the base plate and the middle plate being adapted to receive the preform therebetween;

a top plate disposed above the middle plate, the top plate having an upper array of needle apertures;

a needle bank for holding a plurality of barbed needles; and

a reciprocating device for repeatedly pushing the needles through the upper array of needle apertures, the volume of discrete fibers, and the lower array of needle apertures;

wherein the discrete fibers are inserted through the preform generally in the Z direction so as to provide reinforcement in the Z direction.

36. The apparatus according to claim 35, wherein the discrete fibers are fiberglass.

37. The apparatus according to claim 36, wherein the fiberglass discrete fibers are S-glass discrete fibers.

38. The apparatus according to claim 35, wherein the discrete fibers are graphite.

39. The apparatus according to claim 35, wherein the discrete fibers are polymers.

40. The apparatus according to claim 35, further comprising:

a resilient material disposed between the base plate and the middle plate for providing support for the preform and for retaining the discrete fibers after the discrete fibers have been pushed through the preform.

41. The apparatus according to claim 40, wherein a soluble material is substituted for the resilient material.

42. The apparatus according to claim 40, wherein a meltable material is substituted for the resilient material.

43. The apparatus according to claim 42, wherein the meltable material is thermoplastic.

44. The apparatus according to claim 35, further comprising:
at least one guide rail for guiding and stabilizing the reciprocating device.